INDOOR AIR QUALITY ASSESSMENT

Byrn Mawr Elementary School
35 Swanson Road
Auburn, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality Program
September 2004

Background/Introduction

At the request of Joseph Fahey, Director of Facilities, Auburn Public Schools, the Massachusetts Department of Public Health (MDPH), Center for Environmental Health's (CEH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality concerns at the Bryn Mawr Elementary School (BMES) in Auburn, Massachusetts. The IAQ assessment was prompted by reports of poor ventilation and general indoor air quality complaints.

On May 6, 2004, a visit to conduct an indoor air quality assessment was made to this school by Cory Holmes, an Environmental Analyst in BEHA's Emergency Response/Indoor Air Quality (ER/IAQ) Program. Mr. Holmes was accompanied by Mr. Fahey during the assessment.

The BMES is a one-story brick building constructed in 1949. Modular classrooms were added in 2002. Interior renovations have been conducted in the basement (e.g., walls, floors) over the years; all other equipment in the school appeared to be original. The school contains general classrooms, music room, specialty learning rooms, gymnasium, cafeteria, library, teachers' work/meeting rooms and office space. Windows are openable throughout the building.

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were conducted with the TSI, Q-Trak, IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID).

Results

The BMES houses approximately 260 kindergarten through second grade students and approximately 30 staff members. Tests were taken during normal operations at the school and results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were above 800 parts per million (ppm) in fourteen of twenty-one areas surveyed, indicating inadequate ventilation in the majority of areas surveyed. It is also important to note that areas with carbon dioxide levels below 800 ppm were sparsely populated, unoccupied and/or had windows open, which can greatly reduce carbon dioxide levels. Carbon dioxide levels would be expected to be higher with full occupancy during the heating season when exterior doors and windows are shut.

Fresh air in classrooms is supplied by a unit ventilator (univent) system (Picture 1). A univents draws air from outdoors through a fresh air intake located on the exterior wall of the building (Picture 2) and returns air through an air intake located at the base of the unit (Figure 1). Fresh and return air are mixed, filtered, heated and provided to classrooms through an air diffuser located in the top of the unit. Univents are equipped with control settings of low, medium or high (Picture 3). The majority of univents were either not operable or deactivated during the assessment. A number of univents had reportedly been deactivated due to excessive noise. Several univent air intakes on the exterior of the building were sealed with plywood, preventing the introduction of outside air (Picture 4). Obstructions to airflow, such as papers and books stored on univents and items in front of univent returns were seen in a number of classrooms (Picture 5). In order for univents to provide fresh air as designed, intakes, air diffusers and return vents must remain free of obstructions. Importantly, these units must remain "on" and allowed to operate while rooms are occupied.

Exhaust ventilation is provided by exhaust vents located in ungrated floor level "cubby" holes (Picture 6). These vents were not drawing air and/or obstructed in several areas (Picture 7/Table 1). As with the univents, exhaust vents must be activated and remain free of obstructions to function as designed. Without adequate supply and exhaust ventilation, excess heat and environmental pollutants can build up and lead to indoor air/comfort complaints.

Elevated carbon dioxide levels were also measured in the gym (861 ppm). Mechanical ventilation is provided by AHUs suspended from the ceiling and wall-mounted exhaust vents (Pictures 8 and 9). These systems were not operating during the assessment and appeared to have been deactivated for some time. The conference meeting room has neither openable windows nor mechanical means to introduce fresh air.

Ventilation for modular classrooms is provided by rooftop AHUs (Picture 10). Fresh air is distributed to classrooms via ductwork connected to ceiling-mounted air diffusers. Return vents draw air back to the units through wall-mounted grilles. Thermostats control each heating, ventilating and air conditioning (HVAC) system and have fan settings of "on" and "automatic". Thermostats were set to the "automatic" setting (Picture 11) in all of the modular rooms surveyed during the assessment. The automatic setting on the thermostat activates the HVAC system at a preset temperature. Once the preset temperature is reached, the HVAC system is deactivated. Therefore, no mechanical ventilation is provided until the thermostat re-activates the system.

In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The date of the last balancing of these systems was not available at the time of the assessment.

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health

Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week based on a time weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information on carbon dioxide see Appendix A.

Temperature readings were measured in a range of 70 °F to 76 °F, which were within the BEHA comfort guidelines the day of the assessment. The BEHA recommends that indoor air temperatures be maintained in a range between 70 °F to 78 °F in order to provide for the comfort of building occupants. A number of temperature control complaints were reported. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. In addition, it is difficult to control temperature and maintain comfort without operating the ventilation equipment as designed (e.g., univents and exhaust vents not operating/obstructed).

Relative humidity measurements ranged from 37 to 46 percent, which were within or close to the lower level of the BEHA comfort range. The BEHA recommends that indoor air relative humidity be maintained in a comfort range of 40 to 60 percent. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

Plants were observed in several classrooms. Plants, soil and drip pans can serve as sources of mold growth. Plants should be properly maintained, over-watering of plants should be avoided and drip pans should be inspected periodically for mold growth. Plants should also be located away from ventilation sources to prevent aerosolization of dirt, pollen or mold (Picture 12).

Dehumidifiers were being operated in a number of areas in the basement. Dehumidifiers are typically equipped with reservoirs to collect water. These reservoirs should be emptied and cleaned as per manufacturer's instructions to prevent bacterial and mold growth.

Other Concerns

Indoor air quality can be adversely impacted by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion products include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, BEHA staff obtained measurements for carbon monoxide and PM2.5.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide pollution and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

ASHRAE has adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from 6 criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000a). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS established by the US EPA, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. Outdoor carbon monoxide concentrations were non-detectable (ND). Carbon monoxide levels measured in the school were also ND (Table 1).

As discussed, the US EPA has established NAAQS limits for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits for particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 micrograms per cubic meter ($\mu g/m^3$) in a 24-hour average. This standard was adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM2.5 standard requires outdoor air particulate levels be maintained below 65 $\mu g/m^3$ over a 24-hour average. Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, BEHA uses the more protective proposed PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations the day of the assessment were measured at 31 $\mu g/m^3$ (Table 1). PM2.5 levels measured indoors ranged from 31to 49 $\mu g/m^3$. Frequently, indoor air levels of particulates can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulate during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in the HVAC system; cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors.

Indoor air quality can also be impacted by the presence of materials containing volatile organic compounds (VOCs). VOCs are substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. Outdoor air samples were taken for comparison. Outdoor TVOC concentrations were ND. Indoor TVOC measurements throughout the building were also ND (Table 1).

Please note, TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of TVOC containing products. While TVOC levels were ND, materials containing VOCs were present in the school. Several classrooms contained dry erase boards and dry erase board markers. Materials such as dry erase markers and dry erase board cleaners may contain VOCs, such as methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve (Sanford, 1999), which can be irritating to the eyes, nose and throat.

Cleaning products and other chemicals were found in floor level cabinets and on counter tops in several classrooms. VOC-containing cleaning products, such as bleach or ammonia-related compounds, contain chemicals that can be irritating to the eyes, nose and throat. These items should be stored properly and out of the reach of students.

The teachers' workroom contains two photocopiers. VOCs and ozone can be produced by photocopiers, particularly if the equipment is older and in frequent use. Ozone is a respiratory irritant (Schmidt Etkin, 1992). The workroom is not equipped with local exhaust ventilation to help reduce excess heat and odors.

Also of note was the amount of materials stored inside classrooms (Picture 13). In a number of classrooms, items were observed on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provides a source for dusts to accumulate. These items (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Dust can be irritating to eyes, nose and respiratory tract. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up.

Conclusions/Recommendations

The conditions noted at the BMES raise a number of issues. General building conditions, the condition of HVAC equipment and the limited availability of replacement parts, if considered individually, present conditions that could degrade indoor air quality. When combined, these conditions can serve to further negatively affect indoor air quality. Some of these conditions can be remedied by actions of building occupants. Other remediation efforts will require alteration to the building structure and equipment. For these reasons a two-phase approach to addressing IAQ problems is recommended. The approach consists of **short-term** measures to improve air quality and **long-term** measures that require planning and resources to adequately address the overall indoor air quality concerns.

The following **short-term** measures should be considered for implementation:

1. Remove plywood from univent fresh air intakes. Examine each univent for function. Survey classrooms for univent function to ascertain if an adequate air supply exists for each room. Consider consulting a heating, ventilation and air conditioning (HVAC) engineer concerning the calibration of univent fresh air control dampers throughout the BMES.
2. Operate all functional ventilation systems throughout the building (e.g., gym, cafeteria, classrooms) continuously during periods of school occupancy and independent of thermostat control. To increase airflow in classrooms, set univent controls to "high".
3. Use openable windows in conjunction with classroom univents and exhaust vents to create air exchange. Care should be taken to ensure windows are properly closed at night and weekends to avoid the freezing of pipes and potential flooding.
4. Set the thermostat for modular classrooms to the fan "on" position to operate the ventilation system continuously during the school day.
5. Inspect exhaust motors and belts for proper function. Repair and replace as necessary.
6. Remove all blockages in classrooms from univents and exhaust vents to ensure adequate airflow.
7. Install a passive vent in the door of the conference meeting room to provide air exchange.

8. Consider adopting a balancing schedule of every 5 years for mechanical ventilation systems, as recommended by ventilation industrial standards (SMACNA, 1994).

9. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

10. Move plants away from univents in classrooms. Avoid over-watering and examine drip pans periodically for mold growth. Disinfect with an appropriate antimicrobial where necessary. Consider reducing the number of plants in some areas.

11. Clean and maintain dehumidifiers as per the manufactures instructions to prevent mold/bacterial growth and associated odors.

12. Change filters for air-handling equipment as per the manufacturer's instructions or more frequently if needed. Vacuum interior of units prior to activation to prevent the aerosolization of dirt, dust and particulates. Ensure filters fit flush in their racks with no spaces in between allowing bypass of unfiltered air into the unit.

13. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.
14. Store cleaning products properly and out of reach of students.
15. Consider adopting the US EPA document (2000b), *Tools for Schools*, to maintain a good indoor air quality environment on the building. This document can be downloaded from the Internet at: http://www.epa.gov/iaq/schools/index.html.
16. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are available from the MDPH's website: http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

The following **long-term measures** should be considered:

1. Contact an HVAC engineering firm for a ventilation systems assessment. Based on the age, physical deterioration and availability of parts for ventilation components, such an evaluation is necessary to determine the operability and feasibility of repairing/replacing the equipment.
2. Determine if existing vents, ductwork, etc. can be retrofitted for (modern) mechanical ventilation.
3. Examine the feasibility of providing mechanical ventilation to the conference meeting room.
4. Consider installing local exhaust vents in teachers' workroom to help reduce excess heat and odors from office equipment.

References

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Picture 1

Classroom Univents

Picture 2

Univent Fresh Air Intake

Picture 3

Univent Control Settings, Note Unit is Manually Deactivated

Picture 4

Univent Air Intake Sealed With Plywood

Picture 5

Univent Return Vent Obstructed by Furniture

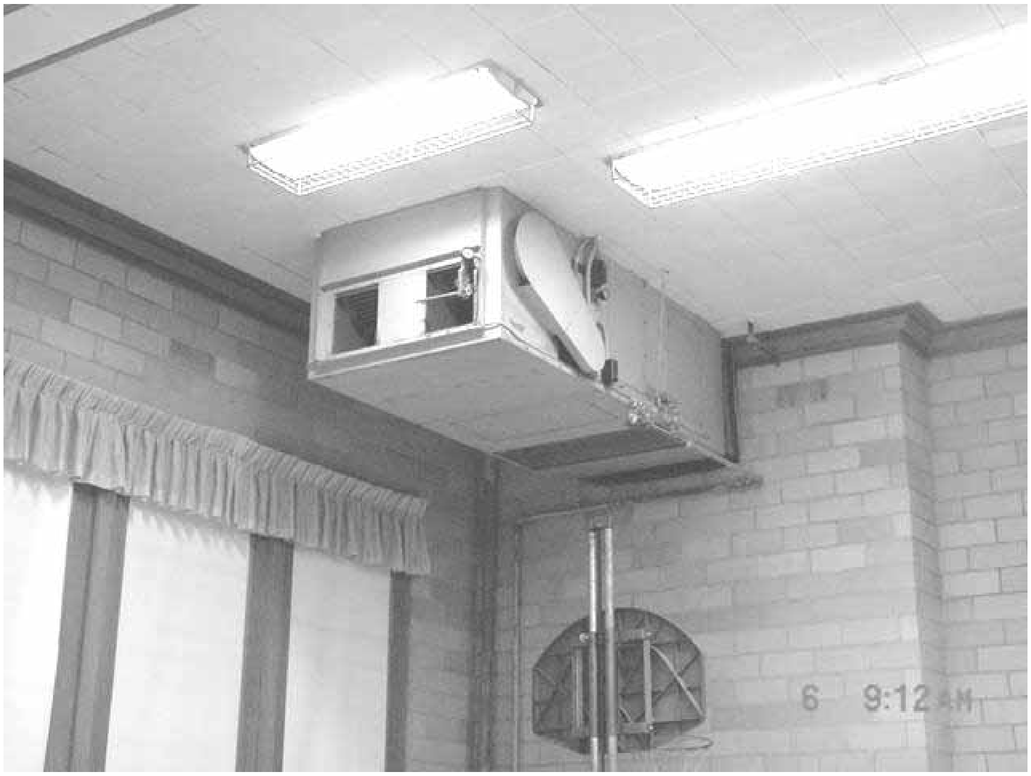
Picture 6

Classroom "Cubby" Exhaust Vents

Picture 7

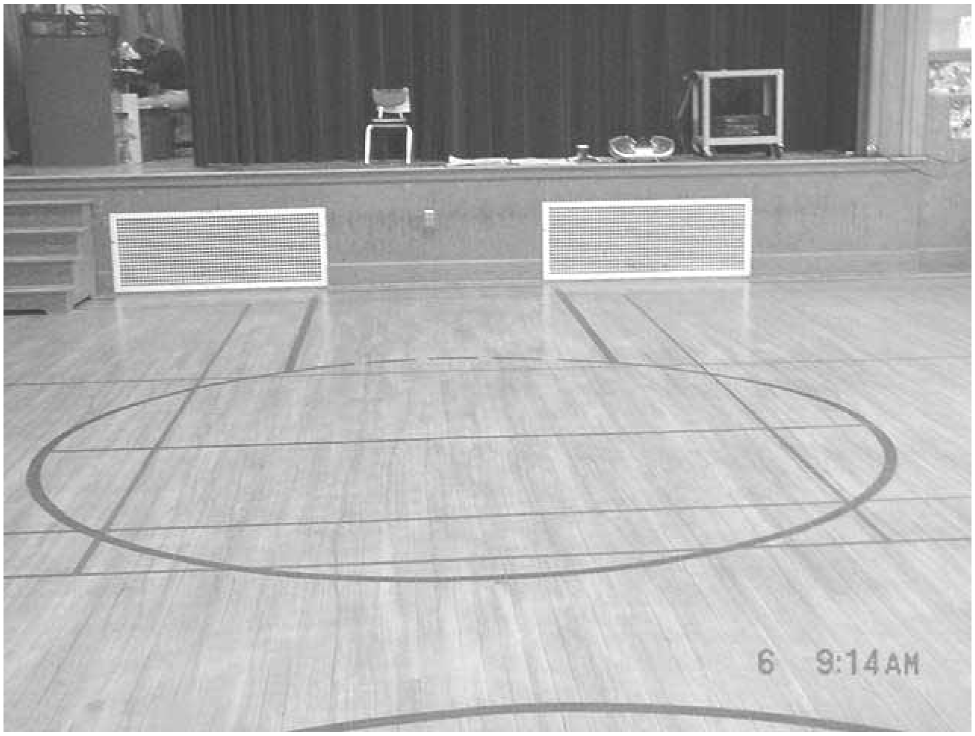
Classroom Exhaust Vents Obstructed by Furniture

Picture 8



AHU in Gym

Picture 9

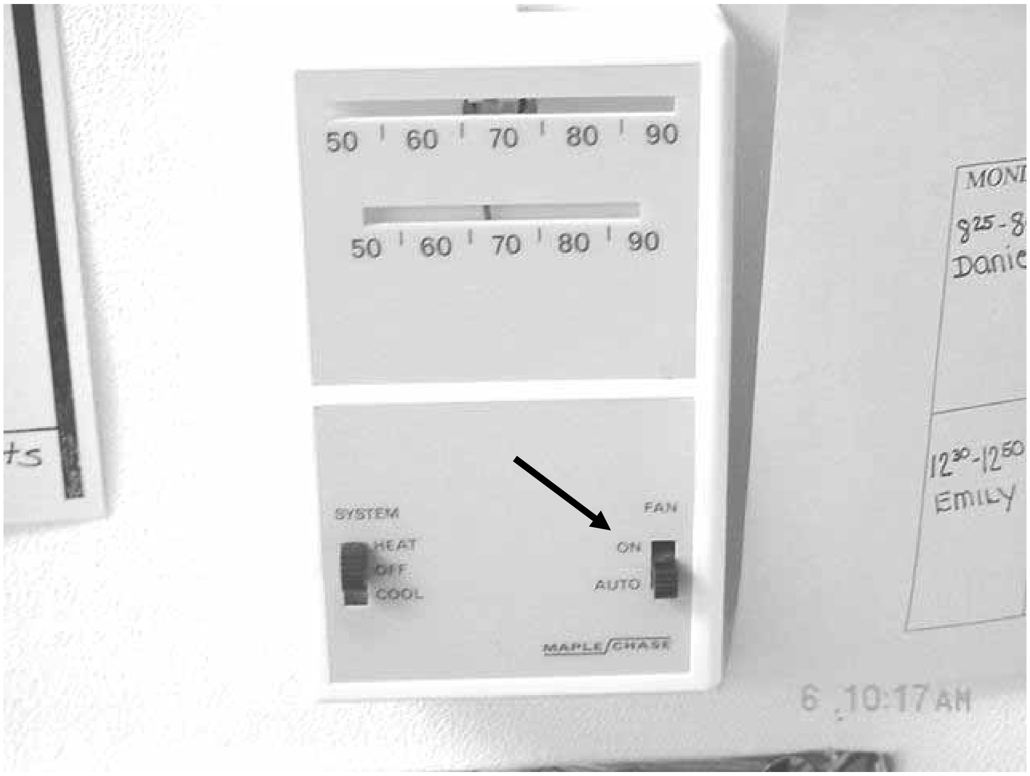


Exhaust Vents in Gym

Picture 10

Rooftop AHU for Modular Classroom

Picture 11



Modular Classroom Thermostat, Note Fan Setting on "Auto"

Picture 12

Plants on/near Classroom Univent

Picture 13

Accumulated Items in Classroom

Bryn Mawr Elementary School

35 Swanson Road, Auburn, MA 01501

Indoor Air Results

May 6, 2004

Table 1

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Background (Outside)	66	44	353	ND	ND	31	-	-	-	-	Clear skies, sunshine; light, variable winds
Teachers' Work Room	71	46	906	ND	ND	39	1	Y	N	N	PC (2); hallway door open
3 Modular Classroom	73	45	1533	ND	ND	34	16	Y	Y Off Ceiling	Y Off Ceiling	DEM; hallway door open; thermostat fan "Auto"
4 Modular Classroom	74	44	1643	ND	ND	49	18	Y	Y Ceiling	Y Ceiling	DEM; hallway door open; thermostat fan "Auto"
5	74	42	1295	ND	ND	32	15	Y	Y Univent	Y Wall	1 of 2 UV on
2	72	40	1727	ND	ND	44	2	Y	Y Off Univent	Y Wall	19 occupants gone 10 min.; hallway door open; exhaust blocked by clutter, furniture
6	74	40	1032	ND	ND	38	18	Y	Y Off Univent	Y Wall	Ceiling fan

ppm = parts per million
µg/m3 = micrograms per cubic meter

AD = air deodorizer
AP = air purifier
aqua. = aquarium

AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials

design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
MT = missing ceiling tile

NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings

sci. chem. = science chemicals
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
WP = wall plaster

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Bryn Mawr Elementary School

35 Swanson Road, Auburn, MA 01501

Table 1

Indoor Air Results

May 6, 2004

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
1	71	38	1600	ND	ND	60	21	Y	Y Off Univent	Y Wall	Plants, exterior door open; supply blocked by clutter, furniture; exhaust blocked by furniture
11A	73	38	823	ND	ND	38	0		Y Off		DEM, plants; hallway door open
8	74	43	1223	ND	ND	41	18	Y	Y Off Univent	Y Wall	DEM, cleaners; hallway door open; supply blocked by clutter; exhaust blocked by clutter, furniture
7	74	41	1108	ND	ND	32	20	Y	Y Off Univent	Y Wall	DEM; exhaust blocked by furniture
12	73	37	987	ND	ND	38	18	Y	Y Univent	Y Wall	1 of 2 UV-On, exhaust vent blocked by furniture
13	72	39	1045	ND	ND	46	19	Y	Y Off	Y	Hallway door open; exhaust blocked by furniture
9	71	38	540	ND	ND	31	20	Y	Y Off	Y	DEM; hallway door open; exhaust blocked by clutter

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Bryn Mawr Elementary School | **Indoor Air Results**

35 Swanson Road, Auburn, MA 01501 | **May 6, 2004**

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11B	73	39	851	ND	ND	37	0	Y	Y Off Univent	Y Wall	Clutter, plants; hallway door open; 1 of 2 UV "on"; exhaust blocked by furniture
Library	72	37	688	ND	ND	32	2	Y	N	N	Dehumidifier
Conference/ Meeting Room	71	38	606	ND	ND	32	2		N	Y Ceiling	DEM, hallway door open; recommend pass vent in door
Speech	70	38	660	ND	ND	34	1	Y	N	N	DEM
Gym	71	40	861	ND	ND	36	2	Y	Y Off Ceiling	Y Off Wall	Hallway door open ~22 occupants gone 2 min.
Teacher's Room	76	39	696	ND	ND	38	1	Y	N	N	Dehumidifier; hallway door open
Guidance	70	38	641	ND	ND	32	0	Y	N	N	Hallway door open

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Cafeteria	72	39	792	ND	ND	32	~100	Y	Y Off Univent	Y Wall	Hallway door open, 3 UV; supply blocked by furniture; exhaust blocked by clutter

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